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Research Article

Evaluation of the Flexural Strength of Cad/Cam Milled Polymethylmethacryateand Rapid Prototype 3d Printed Resin for Long Term Provisional Restorations

Reji Kumar[1], Jayakrishnakumar S[2], Hariharan Ramakrishnan[3]*, Vallabh Mahadevan[3] and Azhagarasan NS[4]

[1]Prosthodontist, Chennai, India

[2] Professor, Department of Prosthodontics, Ragas Dental College, Chennai, India

[3]Professor, Department of Prosthodontics, Ragas Dental College, Chennai, India

[4]Professor and HOD, Ragas Dental College, Chennai, India

***Corresponding Author:** Hariharan Ramakrishnan, Professor, Department of Prosthodontics, Ragas Dental College, Chennai, India.

Orcid: https://orcid.org/0000-0003-4466-5744

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Abstract

Aims: To evaluate and compare the flexural strength of CAD/CAM milled PMMA resin and Rapid prototype3D printed resin for long term provisional restorations.

Materials and Methods: Twenty rectangular shaped samples of dimensions 25mm(l) x 2mm (b) x 2mm (h) were prepared for evaluating the flexural strength according to ISO 10477:2018 (Dentistry-polymer-based crown and veneering materials). CAD/CAM milled PMMA resin samples (Group-I; n=10), Rapid prototype 3D printed resin samples (Group-II; n=10), were fabricated and grouped based on the type of material. All the twenty samples were subjected to 3-point bend test using a universal testing machine at a crosshead speed of 1.0 mm/min until fracture. The flexural strength values were tabulated and statistically analysed using student t- test.

Result: The mean flexural strength for Group I (CAD CAM PMMA) test samples was 86.25 MPa, for Group II (Rapid prototype 3D printed resin) the mean flexural strength was 45.00 MPa. The comparative evaluation of the mean flexural strength of Group I test samples yielded higher flexural strength than Group II test samples and it was found to be statistically highly significant ($p < 0.001$**).

Conclusion: CAD/CAM milled PMMA resin exhibited the maximum flexural strength than Rapid prototyping3D printed resin. Therefore, CAD/CAM PMMA– based polymers can be used for long-term provisional restorations compared to Rapid prototype 3D printed resin.

Keywords: Polymethylmethacrylate; Flexural Strength; Temporary Dental Restorations; Three Dimensional

Introduction

Provisional restorations are important in assessing the treatment plan, so that they should be similar in shape and function to that of the final prosthesis.This prosthetic stage is an essential step in achieving the desired predictable results with regards to esthetic and function [1]. These restorations when employedfor a long-term usage most often will require correction and adjustments. Hence,it is noteworthy to understand the material properties in order to fabricate a durable provisional restoration [2].

The inclusion of dental implants to a treatment plan at times requires anextended lifespan of provisional restoration ranging from few weeks to few months. Implants in esthetic zone often require fixed provisional prosthesis to mould the peri-implant soft tissue ultimately to achieve a better esthetic result [3].

Several materials are used in the construction of provisional prosthesis, namely Auto-polymerized resin, Heat cure polymethyl methacrylateresin Bis-acrylic resin and Visible light cure resin, Bis-

GMA(bisphenol A- glycidyl methacrylate)and TEGDMA(triethylene glycol dimethacrylate) [1].

Heat cure polymethyl methacrylate resin remains the material ofchoice and has been shown to possess greater flexural strength than the other resins. Heat cure PMMA resin can be successfully utilised for long termprovisional prosthesis, as it has adequate flexural strength and wear resistance, however they are susceptible to fracture in situations with less inter-occlusal space and also there colour stability is considered inferior as they tend to attractexternal stains [4].

Over the years CAD/CAM technology has evolved to a greater extent, by which dental biomaterials can be fabricated utilising both the additive and subtractive methods. CAD/CAM manufactured PMMA based polymers have chemical structure resembling conventional PMMA, in addition they are dense,highly Cross-linked, more homogenous, lack of subsurface voids and porosity attributes to the higher flexural strength associated with CAD/CAM milled PMMA [5].

In addition to the subtractive method, Rapid prototyping 3D printing (additive method) is also an emerging technology. Additive manufacturing is defined by the American Society for Testing and Materials as the process of joining materials to make objects from three-dimensional (3D) model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. One attractive feature of this process is that there is no wastage of the material. Traditionally additive manufacturing processes were first used in the 1980s to manufacture prototypes, models, and casting patterns [6].

Typical methods for printing polymer material include fused deposition modelling (FDM), digital light processing (DLP) and steriolithography (SLA). In fused deposition modelling a liquefied filament is extended from a nozzle and material is fused on a scaffold when the nozzle is moved.

The digital light processing (DLP) method involves the polymerization of a photosensitive liquid resin in which a laser is controlled by a light micro- mirror. Steriolithography (SLA) is a method in which a same liquid is polymerized with a single laser beam. In the case of digital light processing (DLP), the digital light processing technique makes use of entire layer of the liquid resin to polymerize at once, making digital light processing (DLP) fasterthan steriolithography (SLA).

The resolution of digital light processing (DLP) and steriolithography (SLA) product is higher than that of the fused deposition modelling (FDM). Hence, digital light processing (DLP) and steriolithography (SLA) can be used to fabricate precision prosthesis, however the liquid is somewhat difficult to handle, and steriolithography (SLA) can be slower than fused deposition modelling (FDM). This study is carried out with digital light processing (DLP) due to its accuracy and advantages.

The flexural strength (Modulus of rupture), of interim prostheses is a critical property, particularly in long-span interim prostheses with short height pontics and connectors and when the patient exhibits parafunctional habits suchas Bruxism and clenching [1]. it is defined as force per unit area at the point of fracture of a test specimen subjected to flexural loading. Higher flexural strength is essential for achieving clinical success with interim prosthesis.

Yao J., *et al*. [7] investigated the flexural strength and marginal accuracy of two traditional Bis-acryl composite interim materials and 2 CAD/CAM interim materials. It was concluded that, CAD/CAM interim materials were stronger and had better marginal accuracy properties than Bis-acryl material ShrutiDigholkar., *et al*. [6] compared the flexural strength and microhardness of provisional restorative materials fabricated utilizing rapid prototyping (RP), Computer Assisted Designing and Computer Assisted Manufacturing (CAD/CAM) and conventional method.

CAD/CAM based provisional material had the highest flexural strength whereas Rapid Prototyping 3D printed and light cured micro hybrid filled composite had the highest microhardness. Bend tests are considered to berelevant as they reflect the direction of occlusal force transmission as encountered in a clinical scenario [8].

Many studies have evaluated and compared the flexural strength for conventional heat-cure PMMA, CAD/CAM PMMA and Bis-acrylate compositeresin (Protemp) provisional materials. Conventional PMMA has a high polymerization shrinkage and poor colour stability, and susceptible to fracture in long-term use [9]. However, limited studies have been reported comparing theflexural strength of CAD/CAM PMMA and Rapid prototyping 3D printed resin.

Aim of the present in-vitro study is to evaluate and compare the flexural strength of CAD/CAM milled PMMA and Rapid prototyping 3D printed resin for long-term fixed provisional restorations. null hypothesis of thepresent study is that there would be no significant difference between the Flexural strength of CAD/CAM milled PMMA resin and Rapid prototyping 3Dprinted resins.

Materials and Methods

A stereolithographic (STL)file was virtually designed using MESHMIXER Software to the required dimensions (25mm × 2mm × 2mm) corresponding to (length, breadth and height) for evaluating the flexural strength according to ISO 10477:2018 (Dentistry-polymer-based crown and veneering materials) to obtain Group I (CAD/CAM PMMA resin) test samples and Group II (Rapid prototype 3D printed resin) test samples.

A 10mm thick CAD/CAM PMMA Blank (Ruthinium disc, Ruthenium groups Pvt. Ltd valsad) was used to mill Ten test samples using CAD/CAM milling machine (ARUM 5 X- 200, Doowon, U.S.A) (Figure 1).

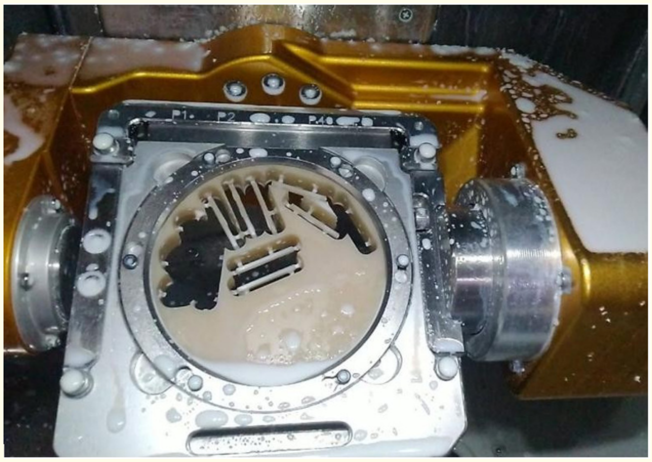

Figure 1: Milling of Group 1 CADCAM PMMA resin blanks.

The samples were subjected to finishing and polishing procedures usingacrylic trimmers and aluminium oxide abrasive papers (120,200,320,400 grit). The dimension (25mm × 2mm × 2mm) of the samples were verified using a digital vernier caliper. Thus, the test samples of CAD/CAM milled PMMA resin (n = 10) were obtained.

A stereolithographic (STL) file was virtually designed using MESHMIXER Software to the required dimensions (25mm × 2mm × 2mm) toobtain the GROUPII(Rapid prototyping 3D printed resin) test samples (n=10).Rapid prototyping 3D printing resin (NEXTDENTC and B Crown and bridge, U.S.A),(shade N2) is used to print Ten samples in a Rapid prototyping 3D printing unit(NEXTDENT 5100 U.S.A)(Figure 2).The samples were subjected to post cure for 60mins in (NEXTDENT Post curing unit), (Figure 3). The samples were subjected to finishing and polishing procedures using acrylic trimmers and aluminium oxide abrasive papers (120,200,320,400grit).The dimension (25 mm × 2mm × 2mm) of the samples were verified using the digital vernier caliper. Thus, test samples of Rapid prototyping 3D printed resin(n = 10), were obtained. A total of twenty test samples were fabricated based on the type of material tested in this study. Twenty test samples were categorized into two groups:

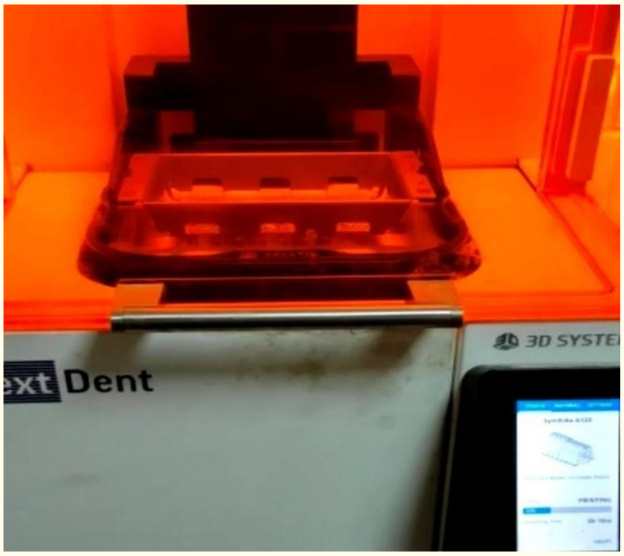

Figure 2: Printing Group II samples in NEXTDENT 5100 3D printing unit.

- **Group I:** CAD/CAM milled PMMA resin samples (n = 10).
- **Group II:** Rapid prototype 3D Printed resin samples (n = 10).

All the twenty samples were tested individually by using 3-point bend test to evaluate the flexural strength in a universal testing machine (ASTM D 790, Instron 3369). The samples were mounted on the vertical supports of the sample holding apparatus which had a support span of 20 mm (Figure 4). After inserting each of the test samples a load was applied at the centre of the sampleat a crosshead speed of 1 mm/min until the samples get fractured. Load deflection curve and the ultimate load to failure was recorded and dis-

Figure 3: Group II samples in NEXTDENT 5100 post curing unit.

Figure 4: Application of load at the center of the sample (3D printed resin).

played bythe computer software of the universal testing machine (Figure 5,6). The maximum load at fracture was recorded in newton (N), and the flexural strengthdata (σ) was calculated in Mega Pascals (MPa) with flexural strength (FS) formula: $\sigma = 3Fd/2wh^2$, where F (N) is the maximum load at fracture, d (mm) isthe distance between vertical support spans, w (mm) is the measured width at the center of the sample, and h (mm) is the height at the centre of the sample.

The flexural strength values of all the twenty test samples were obtained in Mega Pascals (MPa). The results obtained were tabulated and subjected to statistical analysis using the statistical software package SPSS version 20. Mean and standard deviation were estimated from the valuesobtained from each sample for each study group. The data was analysed using student t- test at the significance level of 5%.

Figure 5: Recording of maximum load at fracture (3D printed resin).

Results

The values obtained from the test samples were tabulated and statistically analysed using student t- test.

Basic data for evaluation of mean flexural strength of CAD/CAM milled(PMMA) resin samples (Group-I) is given in table 1.

Sample No	Flexural Strength (MPa)
1	75
2	75
3	75
4	112.5
5	112.5
6	75
7	75
8	75
9	112.5
10	75
Mean	86.25
Standard Deviation	18.11422

Table 1: Basic data for evaluation of mean flexural strength of CADCAM milled (PMMA) resin samples (Group-I).

Basic data for evaluation of mean flexural strength of Rapid prototype3D printed resin samples (Group-II) is given in table 2.

Sample no	Flexural Strength (MPA)
1	75
2	37.5
3	37.5
4	37.5
5	75
6	37.5
7	37.5
8	37.5
9	37.5
10	37.5
Mean	45.00
Standard deviation	15.81139

Table 2: Basic data for evaluation of mean flexural strength of Rapid prototype 3D printed resin samples (Group-II).

Basic data to compare and evaluate the mean flexural strength of CAD/CAMmilled (PMMA) resin samples (Group-I) and Rapid prototype 3D printed resin samples (Group-II) is given in table 3.

Group	Number of Samples	Mean	Std deviation	P value
(Group-I)	10	86.25Mpa	18.11422	0.000**
(Group-II)	10	45.00Mpa	15.81139	

Table 3: Basic data to compare and evaluate the mean flexural strength of CADCAM milled (PMMA) resin samples (Group-I) and of Rapid prototype 3D printed resin samples (Group-II) using student t test.

(p value < 0.001**); Highly Significant.

Discussion

Provisional fixed dental prosthesis had become a routine and an essential component of fixed prosthodontic treatment, involving rehabilitations of tooth supported and implant supported prosthesis, until the definitive restorations are inserted.

The duration between the preparation of the abutment and cementationof the final restoration can vary from a few days to several weeks or even several months for complex cases, when additional therapy like, orthodontic stabilization, extensive periodontal treatment and evaluation of a change in vertical dimension is required. In such situations placement of provisional prosthesis becomes imperative to maintain occlusal stability, function and esthetics [10].

An optimal provisional restoration must be resistant to occlusal forces,stable during function, durable, chemically inert and esthetically acceptable. However, the provisional restorations meant for long-term use should be ableto resist both the functional and parafunctional forces, permit the patient to allow proper oral hygiene maintenance [2].

The provisional restorations are prone to fracture, which may lead to biological, functional, and esthetic problems [5]. Therefore, selection of appropriate material for fabrication of long-term fixed provisional restorationis considered to be critical in fixed prosthodontic treatment.

Materials used in the fabrication of provisional fixed dental prosthesis,mainly fall into two categories based on their chemical compositions: (1) Methyl methacrylate resins and (2) composite.

Flexural strength is an important criterion in determining the mechanical strength and rigidity of the material. Flexural strength, also knownas modulus of rupture or bend strength is a material property, defined as the stress in a material just before it yields in a flexure test. Treatment scenarios involving long span edentulous cases, patients with parafunctional habits andtreatment plan requiring extended duration will all require a provisionalmaterial with adequate flexural strength property.

Conventional PMMA resins are mono-functional, low molecular-weight, linear molecules that exhibit decreased strength and rigidity. Lang., *et al*. 38 investigated fracture resistance of interim fixed partial denture (FPD) materials after storage for 14 days in distilled water and artificial aging and found low mechanical fracture behaviour, and total failure of PMMA materialstested because of deformation during oral simulation. They also found that PMMA materials showed water absorption up to 32µg/mm [1].

CAD/CAM milling of PMMA blanks (subtractive method) has been used in the fabrication of provisional Fixed Dental Prosthesis for the pastfew years. CAD/CAM PMMA-based polymers have chemical structure similar to that of conventional PMMA materials. However, CAD/CAM PMMA-basedpolymers have improved mechanical properties as they are highly cross- linked, more homogenous, and have low water sorption and solubility [12].Additionally, CAD/CAM PMMA-based polymers are stored in air until they are used, which ensures the post-polymerization process occurs accompaniedwith relaxation phenomenon [13].

Rekow [14] reviewed the CAD/CAM PMMA resin used in Dentistry andproposed its use for provisionalization. Manufacturing under industrial conditions permits high-density polymer-based restorations which offer favourable mechanical behaviour and biocompatibility.

Rapid prototype 3D printing (additive method) is an emerging technology for the same. It basically produces solid layers using a concentrated UV light beam that moves on a photosensitive liquid polymer resin placed on a platform. As the first layer is polymerized, the platform is lowered a few microns and the next layer is cured. This process is repeated until the whole solid object is completed. The object is then rinsed with a solvent and placed in a UV oven to thoroughly cure the resin.

Rapid Prototype (3D printing) resin has been used in the productionof various dental prosthesis like fabrication of maxillofacial prosthesis, making complete dentures, crowns, bridges or copings/ resin patterns for the same and making dental casts models, surgical templates for guided surgery of implants and fabrication of pattern for Cast Partial Dentures (CPD) and postand core. However, inspite of its versatile usage, there is a paucity of data on its role in the fabrication of long term provisional fixed dental prosthesis.

The mean flexural strengths of Group I CAD/CAM milled PMMA resin testsamples (86.25 MPa), Group II Rapid prototype 3D printed resin test samples(45.00 MPa) were evaluated.

Alp G., *et al*. [12]. compared the flexural strength of CAD/CAM PMMA- based polymers and conventional interim resin materials using 3-point bend test and the results revealed that flexural strength of CAD/CAM PMMA- based polymers was greater and the least flexural strength was exhibited by conventional PMMA resin.

The comparative evaluation of the mean flexural strength of Group I (CAD/CAM milled PMMA resin) test samples, Group II (Rapid prototype3D printed resin) test samples was found to be statistically highly significant ($p < 0.001^{**}$).

The material used for CAD/CAM milling in this study, ruthenium disk, is a cross-linked polymer of PMMA resin. The cross-linking consists of methacrylic acid ester-based polymers. According to Edelh off., *et al*. [15]. these high-density polymers based on highly cross-linked resins are manufactured in an industrial process thus, exhibiting superior qualities.

Alt., *et al*. [13] who investigated the influence of fabrication method, storage condition and use of different materials on the fracture strength of provisional 3unit FDPs using CAD/CAM technologies and resin-based blankscured under optimal conditions. They concluded that CAD/CAM specimens exhibited increased mechanical strength and had less porosity within therestoration.

Shruti Digholkar., *et al*. [6]. compared flexural strength and microhardness of CAD/CAM milled PMMA resin and Rapid prototype 3D printed resin. The results revealed that, CAD/CAM PMMA specimens exhibited improved flexural strength than Rapid prototype 3D printed resin groups. The results obtained in the present study is comparable to the study done by ShrutiDigholkar., *et al*. where the mean flexural strength of CAD/CAM milled PMMA resin was (104.20 MPa) and Rapid prototype 3D printed resin was (79.54 MPa). In the present study, the mean flexural strength of CAD/CAM PMMA resin was (86.25 MPa) and Rapid prototype 3D printed resin was (45.00MPa).

The mechanical property of the rapid prototype resin is influenced by the method of fabrication, causing the shrinkage of the material during building and post curing. In addition, data conversion and manipulation while formatting into a stereolithography (STL) format could also result in some changes[1]. Therefore, it can be postulated that Rapid Prototype resin group haslesser flexural strength than CAD/CAM resin group.

Thus, the null hypothesis of this study is rejected, because the present study had revealed that there was statistically highly significant difference in the flexural strength of CAD/CAM milled PMMA polymers andRapid prototype 3D printed resin.

Limitations of this study was that it was performed under Invitro specifications. Factors that ascertain the physical properties of rapid prototype3D printing polymer are many, such as the method of polymerization, additionof reinforcement fibers and the effect of cleansing solvent etc. Hence, more additional studies should be conducted with respect to different physical parameters. The effect of thermocycling on the fatigue strength and wear resistance should also be evaluated in future.

Conclusions

- CAD/CAM milled PMMA resin exhibited the maximum and greaterflexural strength than Rapid prototype 3D printed resin samples and was highly significant.
- CAD/CAM milled PMMA resin could be used as long-term provisional restoration in a clinical situation.

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